

western United States has advanced east and south of New Orleans, La. The general aerological situation again indicates a recurve east of the Florida coast.

By the morning of September 20 the hurricane's recurving process from a west-northwest direction to north has almost been completed. The 10,000-foot chart shows conditions are returning to normal over the Windward Islands, while the hurricane circulation has pulled the northerly anticyclonic circulation rapidly southeastward during the past 24 hours over the entire eastern Gulf of Mexico, completely wiping out the equatorial salient present there the day before, except near Jacksonville, Fla. Along the Atlantic coast north of Jacksonville, the tropical current remains to a great depth, Charleston, S. C., reporting altocumulus and Cape Hatteras, N. C., cirrus, from the south.

In this paper no complete or rigorous analyses of the various upper-air charts have been attempted, nor have all the forces influencing the storms' directions of movement

been enumerated. Rather, the purpose has been to point out the extent of the aerological information now available in the Tropics or semi-tropics south and east of the United States, and some of the possibilities of the use of pilot-balloon and other upper-air data in the hurricane warning service and the great need of a more comprehensive airplane or radio-meteorograph program in this region.

- (1) Calvert, E. B. The Hurricane Warning Service and its Reorganization. National Research Council, *Reports and Papers of the 1935 Meeting of the American Geophysical Union*, pp. 117-121.
- (2) Mitchell, C. L. West Indian Hurricanes and Other Tropical Cyclones of the North Atlantic Ocean. MONTHLY WEATHER REVIEW Supplement No. 24, p. 4.
- (3) *Ibid*, p. 17.
- (4) Bowie, E. H. Formations and Movement of West Indian Hurricanes, MONTHLY WEATHER REVIEW, April 1922, pp. 173-179.
- (5) Scofield, Edna. On the Origin of Tropical Cyclones, *Bulletin American Meteorological Society*, June 1938, pp. 244-256.

## A DEW-POINT RECORDER FOR MEASURING ATMOSPHERIC MOISTURE

By C. W. THORNTHWAITTE and J. C. OWEN

[U. S. Soil Conservation Service, Washington, September 5, 1940]

For many years an urgent need for measurements of evaporation from land surfaces (fields and watersheds) as well as from water surfaces has been felt by agronomists, hydrologists, and climatologists. Attempts at correlating observations from various types of evaporation pans and atmometers with the evaporation from natural surfaces have been made. Many empirical formulae have been derived for determining evaporation from water surfaces.

Not until recent researches in aerodynamics revealed the nature of turbulent interchange in the levels of the atmosphere near the ground was it possible to devise a method for measuring evaporation from both land and water surfaces. The method depends on the measurement of atmospheric moisture at two levels near the evaporating surface and the intensity of turbulent mixing between them. It has been described in detail in a number of recent publications.<sup>1 2 3 4 5</sup>

The method required an accurate means of measuring the concentration of moisture in the atmosphere. For that reason all of the familiar devices for measuring humidity have been tested and evaluated and some new ones developed; a detailed report on hygrometry of the atmosphere is in preparation and will be published elsewhere. It is the purpose of this note to describe a new dew-point recorder which may be adapted to the needs of other workers in meteorology and allied fields.

The simplest and one of the earliest methods of measuring the concentration of moisture in the atmosphere is to determine the dew point. Air is cooled until its moisture reaches the point of saturation; the temperature is then observed and the vapor pressure is obtained by referring to appropriate hygrometric tables. This method depends on the fact that the pressure of water vapor does not change as the air is cooled but remains the same until saturation is reached. The temperature at which the air becomes saturated is called the dew point.

All types of apparatus for determining the dew point possess a surface—usually a polished metal mirror exposed to the air so that condensed moisture can be detected—that can be cooled several degrees below air temperature and whose temperature can be observed. The exposed surface is cooled slowly until condensation appears, at which time its temperature is observed. This temperature is the dew point.

The most familiar dew-point hygrometer is a modification by Alluard of an apparatus designed nearly a century ago by Regnault. It consists of a small rectangular metal box whose surface is silver plated and polished. The box contains ether which is vaporized and cooled as air is forced through it. The surface of the box is similarly cooled and the temperature at which dew is observed to appear and disappear upon it is determined from a sensitive thermometer suspended in the ether.

The principle of the dew-point hygrometer has been used in the design of an instrument, illustrated in figure 1, which will give a continuous record of the dew point of the atmosphere.<sup>6</sup>

The essential element of the instrument is a polished metal mirror whose temperature can be controlled at the dew point and recorded. A thin, polished, chrome-plated, copper disk (10) approximately the diameter of a dime is affixed to the end of a copper rod (11) which is inserted through a stopper (12) of low heat conductivity into a conventional thermos bottle (14) which contains a cooling medium such as water-ice with salt, or dry ice with or without alcohol. Heat is conducted downward along the

<sup>6</sup> A number of instruments for use in determining the moisture concentration of flue gases and the dew point of distillates or for use in controlling air-conditioning equipment have been described in the literature or in patent applications. They are designed for industrial uses and are not suitable for making meteorological observations. Following are a few selected references:

Frank, A. K. *Gen. Elect. Rev.* 41: 435-437, illus., 1938.  
 Hixson, Arthur W., and White, G. Edwin. *Indus. and Engin. Chem. Analyt. Ed.* 10: 235-240, 1938.  
 Johnstone, Henry Fraser. *Ill. Engin. Expt. Sta. Cir.* 20: 5-22, illus., 1929.  
 Stack, S. S. *Gen. Elect. Rev.* 41: 106-108, 1938.  
 Winkler, C. A. *Canad. Jour. Res. Sect. D, Zool. Sci.* 17: 35-38, illus., 1939.  
 Tomlinson, Malcolm Claire Weyant. Device for determining the condition of a gas. (U. S. Patent No. 1,883,116.) October 18, 1932.  
 Deniston, Robert F., and Hawthorne, Wendell P. Apparatus for determining the dew point of a vapor product. (U. S. Patent No. 2,106,683.) January 25, 1938.  
 Anderson, Samuel M. Fluid-conditioning method and apparatus. (U. S. Patent No. 1,789,468.) January 13, 1931.  
 Johnson, James Yate. Improvements for measuring the humidity of gases or gaseous mixtures. (British Patent No. 517,306.) August 12, 1929.  
 Griffiths, Ezer, and Campbell, Norman Robert. Improvements for hygrometric apparatus. (British Patent No. 350,774.) June 19, 1930.

<sup>1</sup> Thornthwaite, C. W. *Ecology* 21: 17-28, illus., 1940.

<sup>2</sup> Thornthwaite, C. W., and Holzman, Benjamin. *U. S. Monthly Weather Rev.* 67: 4-11, illus., 1939.

<sup>3</sup> Thornthwaite, C. W., and Holzman, Benjamin. *Natl. Res. Council, Amer. Geophys. Union Trans., Ann. Meeting* 20: 680-686, illus., 1939.

<sup>4</sup> Thornthwaite, C. W., and Holzman, Benjamin. *Natl. Res. Council, Amer. Geophys. Union Trans., Ann. Meeting* 21: 510-511, 1940.

<sup>5</sup> Thornthwaite, C. W., and Holzman, Benjamin. *U. S. Dept. Agr. Yearbook* 1841, [in press.]

copper rod and the mirror is cooled. Embedded into the end of the rod directly beneath the mirror is a small electrical heating element (16) which counteracts the flow of heat from the mirror when the circuit is closed. Light from an incandescent bulb (17) is reflected from the surface of the mirror to a photoelectric cell (18). The electric current generated by the photoelectric cell operates a sensitive relay which in turn energizes a power relay (19), whereby a switch (20) is opened against the action of a spring (21), preventing the operation of the heating element (16) beneath the mirror.

Heat from the mirror is conducted along the rod until moisture from the surrounding atmosphere condenses on

varying only slightly above and below as it is alternately heated and cooled. The temperature is determined by means of a thermocouple, the cold junction of which is a part of the mirror and the warm junction maintained at a standard temperature. Any standard electrical recorder may be used to obtain a record of the dew point.

For use in the dew-point instrument a photographic recorder has certain points of superiority over one which operates electrically. The thermocouple is connected through a galvanometer. A light beam, reflected by the galvanometer mirror, is directed through a slot onto sensitized photographic paper which revolves on a drum or cylinder. A switch in the light circuit is attached to the

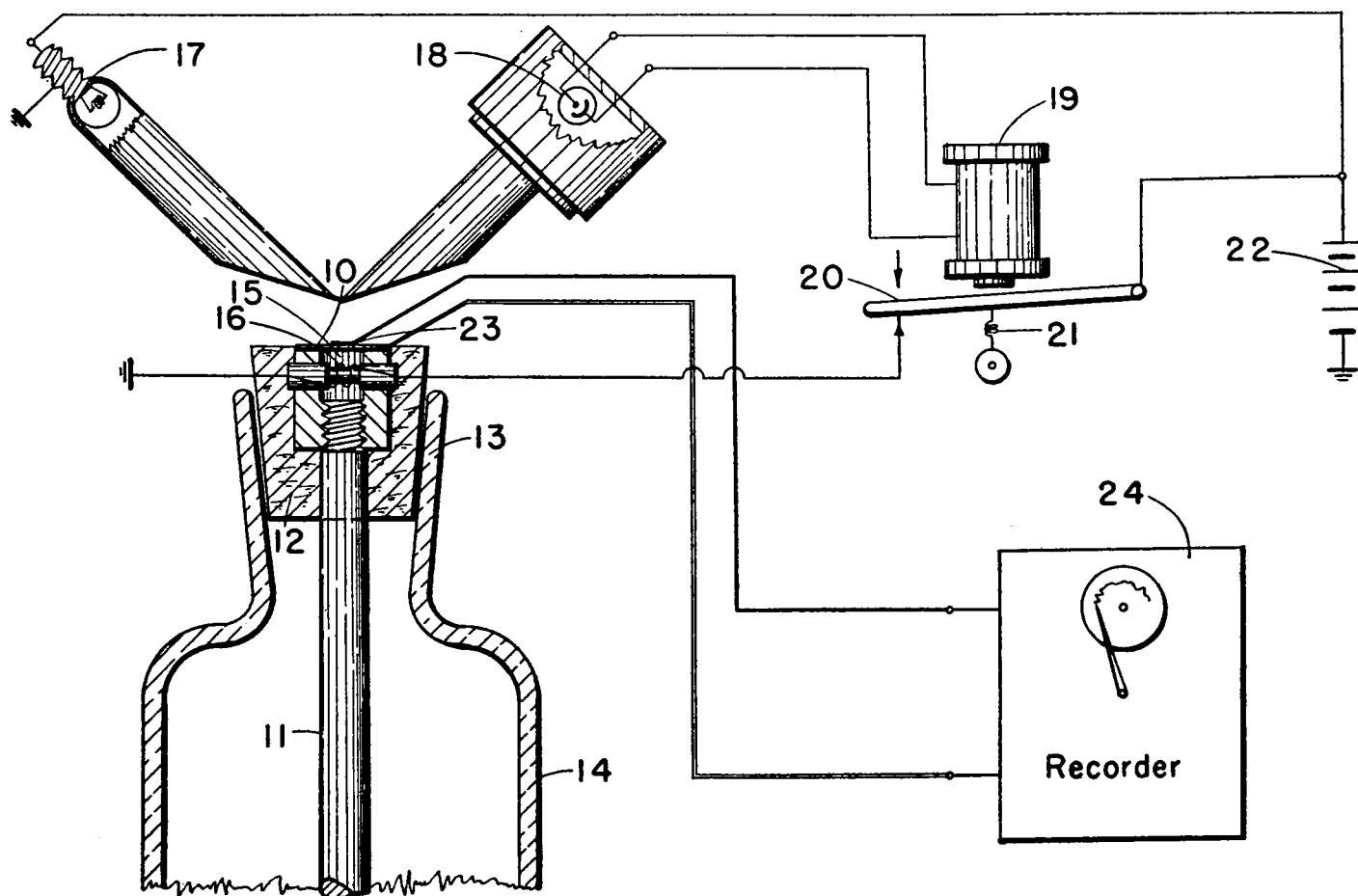


FIGURE 1.—Schematic representation of dew-point recorder.

its reflecting surface. This condensation lowers the reflecting efficiency of the mirror and the light reaching the photoelectric cell is reduced and the current generated is no longer sufficient to energize the relay (19). Consequently, the switch (20) is closed by the spring (21), and the heating element warms the mirror to a point where the condensation formed on its surface is evaporated. The reflecting efficiency of the mirror is thereby restored, the photoelectric cell is again excited and the switch opened by the power relay. The heating element then stops functioning, permitting heat from the mirror to flow along the rod and the entire cycle of operation is repeated.

A mere film of moisture on the mirror, invisible to the eye, is sufficient to reduce the output of the photoelectric cell by 10 microamperes, which is the range within which a sensitive relay will operate. Consequently, the temperature of the mirror remains very close to the dew point,

power relay (19) so that the light flashes momentarily just as the incipient condensation appears on the mirror. Thus, the record is a series of points all at the dew point rather than a continuous, wavy line ranging above and below the dew point. Since a complete cycle requires only about 50 seconds the series of points approximate a continuous line.

In figure 2, the record of depression of the dew point below atmospheric temperature for a period of 14 hours on June 19–20, 1940, is compared with a record of relative humidity for the same period produced by a hair hygrometer. The general pattern of both curves is the same but the much greater sensitivity and greater degree of refinement of the dew-point record is apparent.

The instrument described above employs mechanical relays for opening and closing the circuit to the heater that is beneath the mirror. It is, of course, entirely feasible to use an electrical circuit in which radio tubes

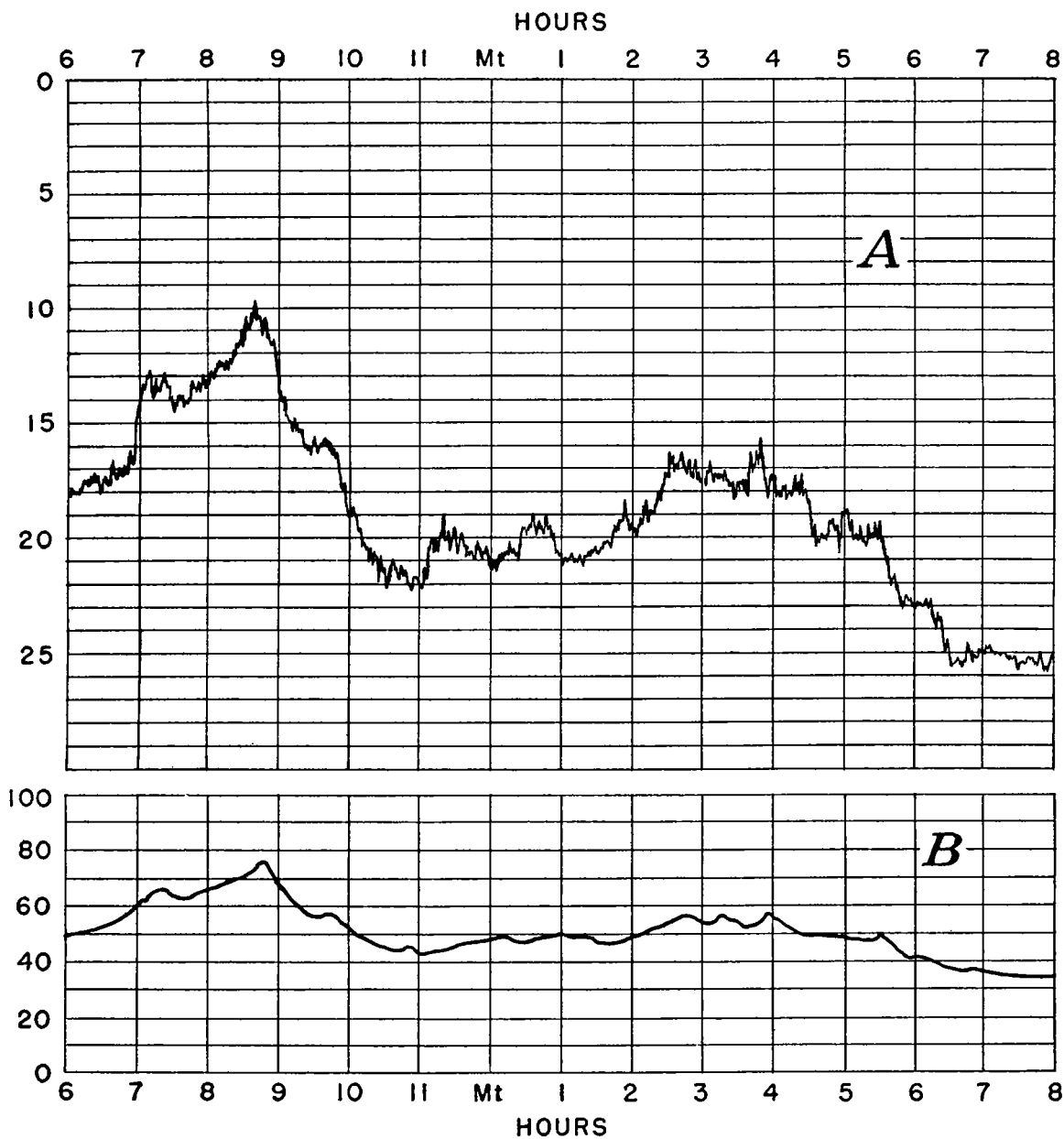


FIGURE 2.—Record of dew-point depression in °F. (A) and relative humidity in percent (B) for the period 6:00 p. m., June 19–8:00 a. m., June 20, 1940, at Arlington, Va.

replace mechanical relays. In fact, by means of radio tubes it should be possible to build a circuit such that the current to the heater varies inversely as the reflective quality of the mirror. Then as moisture begins to appear

on the mirror the heat applied to it will increase and the temperature of the mirror will be maintained continuously at the dew point, or at a level that bears a constant relation to it.

## NOTES AND REVIEWS

W. J. HUMPHREYS. *Physics of the Air*. 3d edition. New York (McGraw-Hill Book Co.), 1940. 676 pp., 226 figs.

In the revision of this standard treatise, care has been taken not to alter the character or scope of the book. It remains a complete treatment of all types of physical phenomena in the atmosphere—thermodynamic, dynamic, electrical, acoustic, and optical—discussed from the physical point of view and, so far as possible, on an exact mathematical basis, but easily understandable by any reader who is familiar with elementary calculus and general physics; it is in general limited to the physical explanations of the phenomena, including but little descriptive meteorology and only occasional and incidental references to the working procedures of practical and applied meteorology or forecasting. The purpose of the book is to provide the reader with the sound foundation of scientific understanding of atmospheric phenomena in general that everyone engaged in any type of either practical or the-

oretical meteorological work should have; and although, since the appearance of the first edition, several other books on physical and dynamical meteorology have been published, there still is no other one treatise of like character and equally comprehensive scope in any language.

In this new edition, the type has been entirely reset, so that no restrictions were imposed on the character of the revisions. Deletions, modifications and additions occasioned by the advances in meteorological knowledge during the past 12 years have been freely introduced in large numbers throughout the work; but no extensive rewriting was necessary. One of the most striking changes from the preceding edition is the section on conditions in the very high atmosphere, pp. 75-78. Many of the former illustrations have been replaced by new ones based on later data. The revisions have increased the size of the book by about 20 pages.

## METEOROLOGICAL AND CLIMATOLOGICAL DATA FOR NOVEMBER 1940

[Climate and Crop Weather Division, J. B. KINCKEL in charge]

### AEROLOGICAL OBSERVATIONS

By EARL C. THOM

The mean surface temperatures were below normal over most of the country during November (chart I), with mean temperature from 8° to 10° F. lower than normal in the northern portion of the Rocky Mountain Plateau region. Temperatures were slightly above normal for the month in most of the extreme eastern portion of the country, as well as along the Gulf coast and along the Pacific coast southward from central Oregon.

At the 1,500 m. level the directions of the resultant winds at most stations were south of normal for the month. The opposite turning occurred over the New England States, the Great Lakes and over the Central Appalachian region as well as over a small area in the west central part of the country. As will be noted from chart IX none of the pilot-balloon stations located along the Pacific coast, in the North Central States, or in the northeastern part of the United States had 10 or more 5 a. m. balloon observations which reached the level of 3,000 m. Except at Atlanta, Ga., the direction of the resultant winds were south of the normal direction at the 3,000 m. level for all stations for which this comparison was made. At 5,000 meters the direction of the 5 p. m. resultant wind was slightly north of the corresponding 5 a. m. normal for the month at Billings, Mont., while the direction of the 5 p. m. resultant wind at Omaha, Nebr., agreed with the morning normal for the month. At no other stations in the northern half of the country did 10 or more 5 p. m. balloon observations reach 5,000 meters during the month (see chart X). In the southern half of the country the directions of the 5 p. m. resultant winds were north of the corresponding 5 a. m. normals along the Pacific coast and were south of these normals to the eastward.

The 5 a. m. resultant velocities at 1,500 meters were lower than normal for the month, except that small positive departures occurred in the extreme northwest and in

a narrow strip in the east central and south central parts of the country. At the 3,000 m. level 5 a. m. resultant velocities were below normal over the northern half of the Rocky Mountain Plateau and were above normal to the east and south of this area. As noted above, the 5 a. m. resultants at 3,000 meters were not available this month for a considerable part of the country. Resultant velocities observed at 5 p. m. were above the corresponding 5 a. m. normals for the month at 5,000 meters at all stations for which such data were computed. The afternoon resultant velocities at this level were generally much higher than the a. m. normals, the largest positive departure, 14.7 m. p. s., being observed at St. Louis, Mo.

The agreement between the mean surface temperature and the shift in the direction of the resultant from normal that had been apparent for several past months was not in evidence in November at any of the three lower levels, 1,500 meters, 3,000 meters, or 5,000 meters.

At the 1,500 m. level the directions of the 5 p. m. resultant winds were north of the direction of the corresponding 5 a. m. winds over the southeast and the Gulf coast, were south of the morning winds over the northeast and north central regions and showed no well defined tendency over the rest of the country. As noted before, a number of pilot-balloon stations did not have 5 a. m. resultants computed this month for the 3,000 m. level. Data available, however, would indicate a tendency of the direction of the resultant wind to shift to the southward during the day at this level over the central and west central parts of the country with no well-defined tendency over other areas.

The 5 p. m. resultant velocities for the month were higher than the corresponding 5 a. m. velocities at 1,500 meters along the Pacific coast and the northern half of the Atlantic coast and were lower than the morning velocities over most of the remainder of the country. At 3,000 meters the increases and decreases in resultant velocity from 5 a. m. to 5 p. m. were well distributed.